# CHAPTER 8 (Odd)

1. $V_{ab} = E + IR = 10\text{ V} + (6\text{ A})(3\ \Omega) = \mathbf{28\text{ V}}$

3. a. $I_1 = \dfrac{E}{R_1} = \dfrac{24\text{ V}}{2\ \Omega} = \mathbf{12\text{ A}},\ I_{R_2} = \dfrac{E}{R_2 + R_3} = \dfrac{24\text{ V}}{6\ \Omega + 2\ \Omega} = \dfrac{24\ \Omega}{8\ \Omega} = 3\text{A}$

   KCL: $I + I_s - I_1 - I_{R_2} = 0$

   $I_s = I_1 + I_{R_2} - I = 12\text{ A} + 3\text{ A} - 4\text{ A} = \mathbf{11\text{ A}}$

   b. $V_s = E = 24\text{ V}$

   VDR: $V_3 = \dfrac{R_3E}{R_2 + R_3} = \dfrac{2\ \Omega(24\text{ V})}{6\ \Omega + 2\ \Omega} = \dfrac{48\text{ V}}{8} = \mathbf{6\text{ V}}$

5. a. $I = \dfrac{E}{R_s} = \dfrac{18\text{ V}}{6\ \Omega} = \mathbf{3\text{ A}},\ R_p = R_s = \mathbf{6\ \Omega}$

   b. $I = \dfrac{E}{R_s} = \dfrac{9\text{ V}}{2.2\text{ k}\Omega} = \mathbf{4.091\text{ mA}},\ R_p = R_s = \mathbf{2.2\text{ k}\Omega}$

7. a. CDR: $I_L = \dfrac{R_s(I)}{R_s + R_L} = \dfrac{4\ \Omega(12\text{ A})}{4\ \Omega + 2\ \Omega} = \mathbf{8\text{ A}}$

   b. $E_s = IR = (12\text{ A})(4\ \Omega) = 48\text{ V}$

   $R_s = 4\ \Omega$

   $I = \dfrac{E_s}{R_s + R_L} = \dfrac{48\text{ V}}{4\ \Omega + 2\ \Omega} = \mathbf{8\text{ A}}$

9. $I_T\uparrow = 7\text{ A} - 3\text{ A} = 4\text{ A}$

   CDR: $I_1 = \dfrac{R_2(I_T)}{R_1 + R_2} = \dfrac{6\ \Omega(4\text{ A})}{4\ \Omega + 6\ \Omega} = \mathbf{2.4\text{ A}}$

   $V_2 = I_T(R_1 \| R_2) = 4\text{ A}(2.4\ \Omega) = \mathbf{9.6\text{ V}}$

11. a. $I = \dfrac{E}{R_2} = \dfrac{12\text{ V}}{2.2\text{ k}\Omega} = \mathbf{5.4545\text{ mA}},\ R_p = \mathbf{2.2\text{ k}\Omega}$

   b. $I_T\uparrow = 8\text{ mA} + 5.4545\text{ mA} - 3\text{ mA} = 10.4545\text{ mA}$

   $R' = 6.8\text{ k}\Omega \| 2.2\text{ k}\Omega = 1.662\text{ k}\Omega$

   $V_1 = I_TR' = (10.4545\text{ mA})(1.662\text{ k}\Omega)$

   $= \mathbf{17.375\text{ V}}$

   c. $V_1 = V_2 + 12\text{ V} \Rightarrow V_2 = V_1 - 12\text{ V} = 17.375\text{ V} - 12\text{ V}$

   $= 5.375\text{ V}$

   d. $I_2 = \dfrac{V_2}{R_2} = \dfrac{5.375\text{ V}}{2.2\text{ k}\Omega} = \mathbf{2.443\text{ mA}}$

13. (I): $\overset{\curvearrowright}{I_1} \downarrow I_3 \overset{\curvearrowleft}{I_2}$

$$10 - I_1\, 5.6\text{ k}\Omega - I_3\, 2.2\text{ k}\Omega + 20 = 0$$
$$-20 + I_3\, 2.2\text{ k}\Omega + I_2\, 3.3\text{ k}\Omega - 30 = 0$$
$$I_1 + I_2 = I_3$$

$I_1 = I_{R_1} = \mathbf{1.445\ mA}$, $I_2 = I_{R_2} = \mathbf{8.513\ mA}$, $I_3 = I_{R_3} = \mathbf{9.958\ mA}$

(II): $\overset{\curvearrowright}{I_1}$, $\overleftarrow{I_3}$, $\overset{\curvearrowleft}{I_2}$

$$-1.2\text{ k}\Omega\, I_1 + 9 - 8.2\text{ k}\Omega\, I_3 = 0$$
$$-10.2\text{ k}\Omega\, I_2 + 8.2\text{ k}\Omega\, I_3 + 6 = 0$$
$$I_2 + I_3 = I_1$$

$I_1 = \mathbf{2.0316\ mA}$, $I_2 = \mathbf{1.2316\ mA}$, $I_3 = \mathbf{0.8\ mA}$

$I_{R_1} = I_1 = \mathbf{2.0316\ mA}$

$I_{R_2} = I_3 = \mathbf{0.8\ mA}$

$I_{R_3} = I_{R_4} = I_2 = \mathbf{1.2316\ mA}$

15. $I_1 = I_{R_1}$(CW), $I_2 = I_{R_2}$(down), $I_3 = I_{R_3}$(right), $I_4 = I_{R_4}$(down)
$I_5 = I_{R_5}$(CW)

a.
$$E_1 - I_1R_1 - I_2R_2 = 0$$
$$I_2R_2 - I_3R_3 - I_4R_4 = 0$$
$$I_4R_4 - I_5R_5 - E_2 = 0$$
$$I_1 = I_2 + I_3$$
$$I_3 = I_4 + I_5$$

b.
$$E_1 - I_2(R_1 + R_2) - I_3R_1 = 0$$
$$I_2R_2 - I_3(R_3 + R_4) + I_5R_4 = 0$$
$$I_3R_4 - I_5(R_4 + R_5) - E_2 = 0$$

c.
$$\begin{aligned} I_2(R_1 + R_2) &+ I_3R_1 && + 0 &&= E_1 \\ I_2(R_2) &- I_3(R_3 + R_4) && + I_5R_4 &&= 0 \\ 0 &+ I_3R_4 && - I_5(R_4 + R_5) &&= E_2 \end{aligned}$$

$$3I_2 + 2I_3 + 0 = 10$$
$$1I_2 - 9I_3 + 5I_5 = 0$$
$$0 + 5I_3 - 8I_5 = 6$$

d. $I_3 = I_{R_3} = \mathbf{-63.694\ mA}$

17. a. $\overset{\curvearrowright}{I_1}\ \overset{\curvearrowright}{I_2}$

$$4 - 4I_1 - 8(I_1 - I_2) = 0$$
$$-8(I_2 - I_1) - 2I_2 - 6 = 0$$

$I_1 = -\frac{1}{7}\ \text{A}$, $I_2 = -\frac{5}{7}\ \text{A}$

$I_{R_1} = I_1 = -\frac{1}{7}\ \text{A}$

$I_{R_2} = I_2 = -\frac{5}{7}\ \text{A}$

$I_{R_3} = I_1 - I_2 = \left[-\frac{1}{7}\ \text{A}\right] - \left[-\frac{5}{7}\ \text{A}\right] = \frac{4}{7}\ \text{A}$ (dir. of $I_1$)

b. $I_1$ $I_2$

$$-10 - 4I_1 - 3(I_1 - I_2) - 12 = 0$$
$$12 - 3(I_2 - I_1) - 12I_2 = 0$$

$$I_1 = \mathbf{-3.0625\ A},\ I_2 = \mathbf{0.1875\ A}$$

$$I_{R_1} = I_1 = \mathbf{-3.0625\ A}$$
$$I_{R_3} = I_2 = \mathbf{0.1875\ A}$$
$$I_{R_2} = I_1 - I_2 = (-3.0625\text{ A}) - (0.1875\text{ A}) = \mathbf{-3.25\ A}$$

19. (I): $I_1$ $I_2$

$$-25 - 2I_1 - 3(I_1 - I_2) + 60 = 0$$
$$-60 - 3(I_2 - I_1) + 6 - 5I_2 - 20 = 0$$

$$I_1 = \mathbf{1.8701\ A},\ I_2 = \mathbf{-8.5484\ A}$$

$$V_{ab} = 20 - I_2 5 = 20 - (8.5484)(5) = 20\text{ V} - 42.74\text{ V}$$
$$= \mathbf{-22.74\ V}$$

(II): Source conversion: $E = 9$ V, $R = 3\ \Omega$

$I_2$ $I_3$

$$9 - 3I_2 - 4I_2 + 6 - 6(I_2 - I_3) = 0$$
$$-6(I_3 - I_2) - 8I_3 - 4 = 0$$

$$I_2 = \mathbf{1.27}\ldots\quad I_3 = \mathbf{0.26\ A}$$

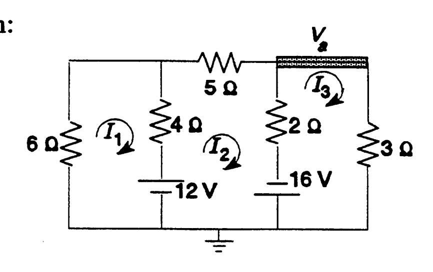
$$V_{ab} = I_2 4 - 6 = (1.274\text{ A})(4\ \Omega) - 6\text{ V}$$
$$= 5.096\text{ V} - 6\text{ V}$$
$$= \mathbf{-0.904\ V}$$

21. a. $I_1$ $I_2$

$$-1I_1 - 4 - 5I_1 + 6 - 1(I_1 - I_2) = 0$$
$$-1(I_2 - I_1) - 6 - 3I_2 - 15 - 10I_2 = 0$$

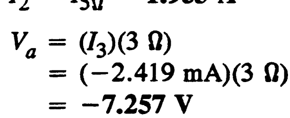
$$I_1 = I_{5\Omega} = \mathbf{72.16\ mA}$$
$$V_a = -4 - (72.16\text{ mA})(6\ \Omega)$$
$$= -4 - 0.433\text{ V}$$
$$= \mathbf{-4.433\ V}$$

b. Network redrawn:




$$-6I_1 - 4(I_1 - I_2) - 12 = 0$$
$$12 - 4(I_2 - I_1) - 5I_2 - 2(I_2 - I_3) + 16 = 0$$
$$-16 - 2(I_3 - I_2) - 3I_3 = 0$$

$$I_2 = I_{5\Omega} = \mathbf{1.953\ A}$$



$$V_a = (I_3)(3\ \Omega)$$
$$= (-2.419\text{ mA})(3\ \Omega)$$
$$= \mathbf{-7.257\ V}$$

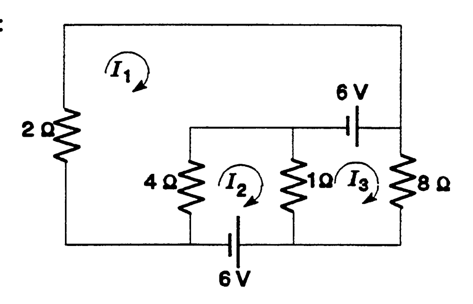
23. a. $I_1 \curvearrowright I_2 \curvearrowright$ $I_4 \curvearrowright I_3 \curvearrowright$

$$-6.8\text{ k}\Omega\, I_1 - 4.7\text{ k}\Omega(I_1 - I_2) + 6 - 2.2\text{ k}\Omega(I_1 - I_4) = 0$$
$$-6 - 4.7\text{ k}\Omega(I_2 - I_1) - 2.7\text{ k}\Omega\, I_2 - 8.2\text{ k}\Omega\,(I_2 - I_3) = 0$$
$$-1.1\text{ k}\Omega\, I_3 - 22\text{ k}\Omega(I_3 - I_4) - 8.2\text{ k}\Omega(I_3 - I_2) - 9 = 0$$
$$5 - 1.2\text{ k}\Omega\, I_4 - 2.2\text{ k}\Omega(I_4 - I_1) - 22\text{ k}\Omega(I_4 - I_3) = 0$$

---

$I_1 = \mathbf{0.0321\ mA}$, $I_2 = \mathbf{-0.8838\ mA}$, $I_3 = \mathbf{-0.968\ mA}$, $I_4 = \mathbf{-0.639\ mA}$

b. Network redrawn:




$$-2I_1 - 6 - 4I_1 + 4I_2 = 0$$
$$-4I_2 + 4I_1 - 1I_2 + 1I_3 - 6 = 0$$
$$-1I_3 + 1I_2 + 6 - 8I_3 = 0$$

---

$I_1 = \mathbf{-3.8\ A}$, $I_2 = \mathbf{-4.2\ A}$, $I_3 = \mathbf{0.2\ A}$,

25. a. $I_1 \curvearrowright I_2 \curvearrowright$

$$(4 + 8)I_1 - 8I_2 = 4$$
$$(8 + 2)I_2 - 8I_1 = -6$$

---

$I_1 = -\frac{1}{7}\text{A}$, $I_2 = -\frac{5}{7}\text{A}$

b. $I_1 \curvearrowright I_2 \curvearrowright$

$$(4 + 3)I_1 - 3I_2 = -10 - 12$$
$$(3 + 12)I_2 - 3I_1 = 12$$

---

$I_1 = \mathbf{-3.0625\ A}$, $I_2 = \mathbf{0.1875\ A}$

27. (I): a. $I_1 \curvearrowright I_2 \curvearrowright$

$$(2 + 3)I_1 - 3I_2 = -25 + 60$$
$$(3 + 5)I_2 - 3I_1 = -60 + 6 - 20$$

---

b. $I_1 = \mathbf{1.871\ A}$, $I_2 = \mathbf{-8.548\ A}$

c. $I_{R_1} = I_1 = \mathbf{1.871\ A}$, $I_{R_2} = I_2 = \mathbf{-8.548\ A}$

$I_{R_3} = I_1 - I_2 = 1.871\text{ A} - (-8.548\text{ A}) = \mathbf{10.419A}$ **(direction of** $I_1$**)**

(II): a. $I_2 \curvearrowright I_3 \curvearrowright$

$$(3 + 4 + 6)I_2 - 6I_3 = 9 + 6$$
$$(6 + 8)I_3 - 6I_2 = -4$$

---

b. $I_2 = \mathbf{1.274\ A}$, $I_3 = \mathbf{0.26\ A}$

c. $I_{R_2} = I_2 = \mathbf{1.274\ A}$, $I_{R_3} = I_3 = \mathbf{0.26\ A}$

$I_{R_4} = I_2 - I_3 = 1.274\text{ A} - 0.26\text{ A} = \mathbf{1.014\ A}$

$I_{R_1} = 3\text{ A} - I_2 = 3\text{ A} - 1.274\text{ A} = \mathbf{1.726\ A}$

29. From Sol. 21(b)

$I_1 \circlearrowright \; I_2 \circlearrowright \; I_3 \circlearrowright$

$$I_1(6 + 4) - 4I_2 = -12$$
$$I_2(4 + 5 + 2) - 4I_1 - 2I_3 = 12 + 16$$
$$I_3(2 + 3) - 2I_2 = -16$$

---

$I_{5\Omega} = I_2 = \mathbf{1.953\ A}$

$I_3 = -2.4186$ A, $\therefore V_a = (I_3)(3\ \Omega) = (-2.4186\ \text{A})(3\ \Omega) = \mathbf{-7.26\ V}$

31. a. $I_1 \circlearrowright \; I_2 \circlearrowright$ / $I_4 \circlearrowright \; I_3 \circlearrowright$

$$I_1(6.8\ \text{k}\Omega + 4.7\ \text{k}\Omega + 2.2\ \text{k}\Omega) - 4.7\ \text{k}\Omega\, I_2 - 2.2\ \text{k}\Omega\, I_4 = 6$$
$$I_2(2.7\ \text{k}\Omega + 8.2\ \text{k}\Omega + 4.7\ \text{k}\Omega) - 4.7\ \text{k}\Omega\, I_1 - 8.2\ \text{k}\Omega\, I_3 = -6$$
$$I_3(8.2\ \text{k}\Omega + 1.1\ \text{k}\Omega + 22\ \text{k}\Omega) - 22\ \text{k}\Omega\, I_4 - 8.2\ \text{k}\Omega\, I_2 = -9$$
$$I_4(2.2\ \text{k}\Omega + 22\ \text{k}\Omega + 1.2\ \text{k}\Omega) - 2.2\ \text{k}\Omega\, I_1 - 22\ \text{k}\Omega\, I_3 = 5$$

---

$I_1 = \mathbf{0.0321\ mA}$, $I_2 = \mathbf{-0.8838\ mA}$, $I_3 = \mathbf{-0.968\ mA}$, $I_4 = \mathbf{-0.639\ mA}$

b. From Sol. 23(b):

$$I_1(2 + 4) - 4I_2 = -6$$
$$I_2(4 + 1) - 4I_1 - 1I_3 = -6$$
$$I_3(1 + 8) - 1I_2 = 6$$

---

$I_1 = \mathbf{3.8\ A}$, $I_2 = \mathbf{-4.2\ A}$, $I_3 = \mathbf{0.2\ A}$

33. (I): $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{3} + \frac{1}{6} + \frac{1}{4}\right] - \frac{1}{4}V_2 = -5 - 3$$
$$V_2\left[\frac{1}{8} + \frac{1}{4}\right] - \frac{1}{4}V_1 = 3 - 4$$

---

$V_1 = \mathbf{-14.86\ V}$, $V_2 = \mathbf{-12.57\ V}$

$V_{R_1} = V_{R_4} = \mathbf{-14.86\ V}$

$V_{R_2} = \mathbf{-12.57\ V}$

$^{+}V_{R_3}{}^{-} = 12\ \text{V} + 12.57\ \text{V} - 14.86\ \text{V} = \mathbf{9.71\ V}$

(II): $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{5} + \frac{1}{3} + \frac{1}{2}\right] - \frac{1}{3}V_2 - \frac{1}{2}V_2 = -6$$
$$V_2\left[\frac{1}{2} + \frac{1}{3} + \frac{1}{4} + \frac{1}{8}\right] - \frac{1}{3}V_1 - \frac{1}{2}V_1 = 7$$

---

$V_1 = \mathbf{-2.556\ V}$, $V_2 = \mathbf{4.03\ V}$

$V_{R_1} = \mathbf{-2.556\ V}$

$V_{R_2} = V_{R_5} = \mathbf{4.03\ V}$

$V_{R_4} = V_{R_3} = 4.03\ \text{V} + 2.556\ \text{V} = \mathbf{6.586\ V}$

35. (I): $\circ V_1$ $\circ V_2$ $\circ V_3$

$$V_1\left[\frac{1}{3} + \frac{1}{6} + \frac{1}{6}\right] - \frac{1}{6}V_2 - \frac{1}{6}V_3 = 5$$

$$V_2\left[\frac{1}{6} + \frac{1}{4} + \frac{1}{5}\right] - \frac{1}{6}V_1 - \frac{1}{5}V_3 = -3$$

$$V_3\left[\frac{1}{6} + \frac{1}{5} + \frac{1}{7}\right] - \frac{1}{5}V_2 - \frac{1}{6}V_1 = 0$$

$\mathbf{V_1 = 7.238\ V,\ V_2 = -2.453\ V,\ V_3 = 1.405\ V}$

(II): Source conversion: $I = 4$ A, $R = 4\ \Omega$

$\circ V_1$ $\circ V_2$ $\circ V_3$

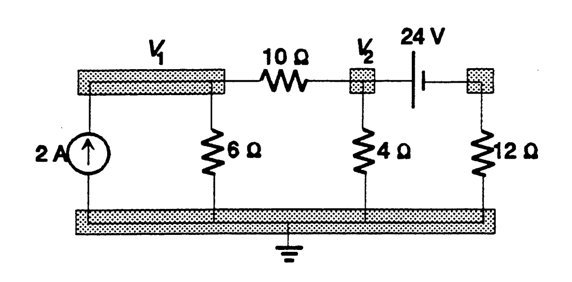
$$V_1\left[\frac{1}{9} + \frac{1}{20} + \frac{1}{20}\right] - \frac{1}{20}V_2 - \frac{1}{20}V_3 = -2$$

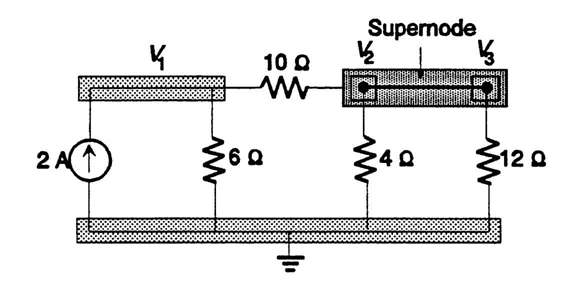
$$V_2\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{18}\right] - \frac{1}{20}V_1 - \frac{1}{20}V_3 = 0$$

$$V_3\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{4}\right] - \frac{1}{20}V_2 - \frac{1}{20}V_1 = 4$$

$\mathbf{V_1 = -6.642\ V,\ V_2 = 1.293\ V,\ V_3 = 10.664\ V}$

37. a.




$$\Sigma I_i = \Sigma I_o$$

Node $V_1$:

$$2\text{ A} = \frac{V_1}{6\ \Omega} + \frac{V_1 - V_2}{10\ \Omega}$$

Supernode $V_2$, $V_3$:

$$0 = \frac{V_2 - V_1}{10\ \Omega} + \frac{V_2}{4\ \Omega} + \frac{V_3}{12\ \Omega}$$

Independent source:

$$V_2 - V_3 = 24\text{ V or } V_3 = V_2 - 24\text{ V}$$

2 eq. 2 unknowns:

$$\frac{V_1}{6\ \Omega} + \frac{V_1 - V_2}{10\ \Omega} = 2\text{ A}$$

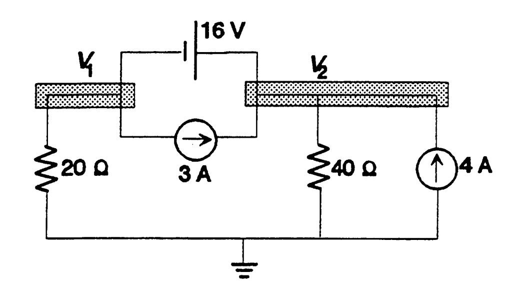
$$\frac{V_2 - V_1}{10\ \Omega} + \frac{V_2}{4\ \Omega} + \frac{V_2 - 24\text{ V}}{12\ \Omega} = 0$$

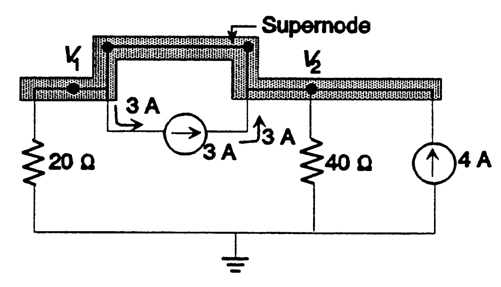
$$0.267V_1 - 0.1V_2 = 2$$
$$+0.1V_1 - 0.433V_2 = -2$$

$\mathbf{V_1 = 10.083\ V,\ V_2 = 6.944\ V}$

$V_3 = V_2 - 24\text{ V} = \mathbf{-17.056\ V}$

b.




$$\Sigma I_i = \Sigma I_o$$

Supernode:

$$3\text{ A} + 4\text{ A} = 3\text{ A} + \frac{V_1}{20\ \Omega} + \frac{V_2}{40\ \Omega}$$

2 eq. 2 unk. $\begin{cases} 4\text{ A} = \dfrac{V_1}{20\ \Omega} + \dfrac{V_2}{40\ \Omega} \\ V_2 - V_1 = 16\text{ V} \end{cases}$

Subt. $V_2 = 16\text{ V} + V_1$

$$4\text{ A} = \frac{V_1}{20\ \Omega} + \frac{(16\text{ V} + V_1)}{40\ \Omega}$$

and $V_1 = \mathbf{48\ V}$

$V_2 = 16\text{ V} + V_1 = \mathbf{64\ V}$

39. (I): a. Note the solution to problem 33(I).

b. $V_1 = \mathbf{-14.86\ V}$, $V_2 = \mathbf{-12.57\ V}$

c. $V_{R_1} = V_{R_4} = V_1 = \mathbf{-14.86\ V}$, $V_{R_2} = V_2 = \mathbf{-12.57\ V}$

$+ V_{R_3} -$ (resistor $R_3$)

$V_{R_3} = V_1 - V_2 + 12\text{ V} = (-14.86\text{ V}) - (-12.57\text{ V}) + 12\text{ V} = \mathbf{9.71\ V}$

(II): a. Note the solution to problem 33(II).

b. $V_1 = \mathbf{-2.556\ V}$, $V_2 = \mathbf{4.03\ V}$

c. $V_{R_1} = V_1 = \mathbf{-2.556\ V}$, $V_{R_2} = V_{R_5} = V_2 = \mathbf{4.03\ V}$

$V_{R_3} = V_{R_4} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{6.586\ V}$

41. a. Note the solution to problem 36(I).
$V_1 = \mathbf{-5.311\ V}$, $V_2 = \mathbf{-0.6219\ V}$, $V_3 = \mathbf{3.751\ V}$
$V_{5\text{A}} = V_1 = \mathbf{-5.311\ V}$

b. Note the solution to problem 36(II).
$V_1 = \mathbf{-6.917\ V}$, $V_2 = \mathbf{12\ V}$, $V_3 = \mathbf{2.3\ V}$

$V_{2\text{A}} = \overset{(+)}{V_2} - \overset{(-)}{V_3} = \mathbf{9.7\ V}$, $V_{5\text{A}} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{18.917\ V}$

43. Source conversion: $I = 1$ A, $R = 6\ \Omega$

$V_1$, $V_3$, $V_2$ (node labels with ground)

$$\left[\frac{1}{6} + \frac{1}{5} + \frac{1}{5}\right]V_1 - \frac{1}{5}V_2 - \frac{1}{5}V_3 = 1$$

$$\left[\frac{1}{5} + \frac{1}{5} + \frac{1}{20}\right]V_2 - \frac{1}{5}V_1 - \frac{1}{5}V_3 = 0$$

$$\left[\frac{1}{5} + \frac{1}{5} + \frac{1}{10}\right]V_3 - \frac{1}{5}V_1 - \frac{1}{5}V_2 = 0$$

$V_{R_5}$ **= 0.1967 V, no**

45. Source conversion: $I = 12$ A, $R = 2$ kΩ

$V_1$, $V_3$, $V_2$ (node labels with ground)

$$\left[\frac{1}{2\text{ k}\Omega} + \frac{1}{33\text{ k}\Omega} + \frac{1}{56\text{ k}\Omega}\right]V_1 - \frac{1}{56\text{ k}\Omega}V_2 - \frac{1}{33\text{ k}\Omega}V_3 = 12$$

$$\left[\frac{1}{56\text{ k}\Omega} + \frac{1}{36\text{ k}\Omega} + \frac{1}{5.6\text{ k}\Omega}\right]V_2 - \frac{1}{56\text{ k}\Omega}V_1 - \frac{1}{36\text{ k}\Omega}V_3 = 0$$

$$\left[\frac{1}{33\text{ k}\Omega} + \frac{1}{3.3\text{ k}\Omega} + \frac{1}{36\text{ k}\Omega}\right]V_3 - \frac{1}{33\text{ k}\Omega}V_1 - \frac{1}{36\text{ k}\Omega}V_2 = 0$$

$I_{R_5}$ **= 0 A, yes**

47. a. ($I_1$, $I_2$, $I_3$ clockwise loop currents)

$(1\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega)I_1 - 2\text{ k}\Omega\, I_2 - 2\text{ k}\Omega\, I_3 = 10$
$(2\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega)I_2 - 2\text{ k}\Omega\, I_1 - 2\text{ k}\Omega\, I_3 = 0$
$(2\text{ k}\Omega + 2\text{ k}\Omega + 2\text{ k}\Omega)I_3 - 2\text{ k}\Omega\, I_1 - 2\text{ k}\Omega\, I_2 = 0$

$I_1 = I_{10V} =$ **3.33 mA**

Source conversion: $I = 10$ V/1 kΩ = 10 mA, $R = 1$ kΩ

$V_1$, $V_3$, $V_2$ (node labels with ground)

$$V_1\left[\frac{1}{1\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega}\right] - \frac{1}{2\text{ k}\Omega}V_2 - \frac{1}{2\text{ k}\Omega}V_3 = 10\text{ mA}$$

$$V_2\left[\frac{1}{2\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega}\right] - \frac{1}{2\text{ k}\Omega}V_1 - \frac{1}{2\text{ k}\Omega}V_3 = 0$$

$$V_3\left[\frac{1}{2\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega} + \frac{1}{2\text{ k}\Omega}\right] - \frac{1}{2\text{ k}\Omega}V_2 - \frac{1}{2\text{ k}\Omega}V_1 = 0$$

$V_1 = 6.67\text{ V} = E - IR_s = 10\text{ V} - I(1\text{ k}\Omega)$

$$I = \frac{10 - 6.67\text{ V}}{1\text{ k}\Omega} = \mathbf{3.33\text{ mA}}$$

b. ($I_1$, $I_2$, $I_3$ clockwise loop currents)

Source conversion: $E = 20$ V, $R = 10\ \Omega$

$(10 + 10 + 20)I_1 - 10I_2 - 20I_3 = 20$
$(10 + 20 + 20)I_2 - 10I_1 - 20I_3 = 0$
$(20 + 20 + 10)I_3 - 20I_1 - 20I_2 = 0$

$I_1 = I_{20V} = 0.8235$ A

10 Ω 8.235 V

20 V $I_1$

$V = 20\text{ V} - 8.235\text{ V} = 11.765\text{ V}$

$$I_s = \frac{V}{R_s} = \frac{11.765\text{ V}}{10\ \Omega} = \mathbf{1.177A}$$

$V_1$ $V_3$ $V_2$

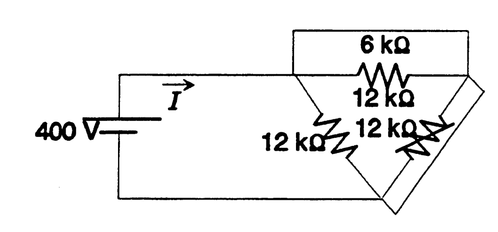
$$V_1\left[\frac{1}{10} + \frac{1}{10} + \frac{1}{20}\right] - \left[\frac{1}{20}\right]V_2 - \left[\frac{1}{10}\right]V_3 = 2$$

$$V_2\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{10}\right] - \left[\frac{1}{20}\right]V_1 - \left[\frac{1}{20}\right]V_3 = 0$$

$$V_3\left[\frac{1}{10} + \frac{1}{20} + \frac{1}{20}\right] - \left[\frac{1}{10}\right]V_1 - \left[\frac{1}{20}\right]V_2 = 0$$

$$I_{R_s} = \frac{V_1}{R_s} = \mathbf{1.177\ A}$$

49. a.




(Y−Δ conversion)

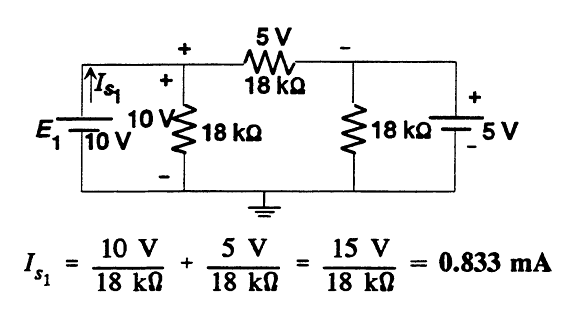
$$I = \frac{400\text{V}}{12\text{ k}\Omega \| 12\text{ k}\Omega \| 6\text{ k}\Omega} = \frac{400\text{ V}}{3\text{ k}\Omega}$$

$= \mathbf{133.33\ mA}$

b. $$I = \frac{42\text{ V}}{(18\ \Omega \| 18\ \Omega) \| [(18\ \Omega \| 18\ \Omega) + (18\ \Omega \| 18\ \Omega)]} = \frac{42\text{ V}}{9\ \Omega \| [9\ \Omega + 9\ \Omega]}$$

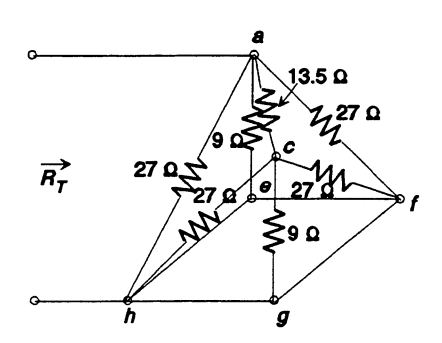
$= \mathbf{7\ A}$ (Y−Δ conversion)

51.




$$I_{s_1} = \frac{10\text{ V}}{18\text{ k}\Omega} + \frac{5\text{ V}}{18\text{ k}\Omega} = \frac{15\text{ V}}{18\text{ k}\Omega} = \mathbf{0.833\ mA}$$

53.




c − g: $27\ \Omega \| 9\ \Omega \| 27\ \Omega = 5.4\ \Omega$

a − h: $27\ \Omega \| 9\ \Omega \| 27\ \Omega = 5.4\ \Omega$

$R_T = 5.4\ \Omega \| (13.5\ \Omega + 5.4\ \Omega)$
$= 5.4\ \Omega \| 18.9\ \Omega$
$= \mathbf{4.2\ \Omega}$

# CHAPTER 8 (Even)

2. a. CDR: $I_{6\Omega} = \dfrac{10\text{ k}\Omega(4\text{ A})}{10\text{ k}\Omega + 8\ \Omega} = 3.997\text{ A}$

   $V_{6\Omega} = I_{6\Omega}(6\ \Omega) = (3.997\text{ A})(6\ \Omega) = \mathbf{23.982\ V}$

   b. $V_{6\Omega} = I_{6\Omega}(6\ \Omega) = (4\text{ A})(6\ \Omega) = \mathbf{24\ V}$. Yes, a good approximation.

4. $V_1 = V_2 = V_s = IR_T = 0.6\text{ A}[6\ \Omega \| 24\ \Omega \| 24\ \Omega] = 0.6\text{ A}\,[6\ \Omega \| 12\ \Omega] = \mathbf{2.4\ V}$

   $I_2 = \dfrac{V_2}{R_2} = \dfrac{2.4\text{ V}}{24\ \Omega} = \mathbf{0.1\ A}$

   $V_3 = \dfrac{R_3 V_s}{R_3 + R_4} = \dfrac{16\Omega(2.4\text{ V})}{24\ \Omega} = \mathbf{1.6\ V}$

6. a. $E = IR_s = (1.5\text{ A})(3\ \Omega) = \mathbf{4.5\ V},\ R_s = \mathbf{3\ \Omega}$

   b. $E = IR_s = (6\text{ mA})(4.7\text{ k}\Omega) = \mathbf{28.2\ V},\ R_s = \mathbf{4.7\ k\Omega}$

8. a. $E = IR_2 = (2\text{ A})(6.8\ \Omega) = \mathbf{13.6\ V},\ R = \mathbf{6.8\ \Omega}$

   b. $\curvearrowright\ I_1 = (12\text{ V} + 13.6\text{ V})/(10\ \Omega + 6.8\ \Omega + 39\ \Omega) = \dfrac{25.6\text{ V}}{55.8\ \Omega} = \mathbf{458.78\ mA}$

   c. $\underset{+-}{V_{ab}} = I_1R_3 = (458.78\text{ mA})(39\ \Omega) = \mathbf{17.89\ V}$

10. a. Conversions: $I_1 = E_1/R_1 = 9\text{ V}/3\ \Omega = \mathbf{3\ A},\ R_1 = \mathbf{3\ \Omega}$

    $I_2 = E_2/R_2 = 20\text{ V}/2\ \Omega = \mathbf{10\ A},\ R_2 = \mathbf{2\ \Omega}$

    b. $I_T\downarrow = 10\text{ A} - 3\text{A} = 7\text{A},\ R_T = 3\ \Omega \| 6\ \Omega \| 2\Omega \| 12\ \Omega$

    $= 2\ \Omega \| 2\ \Omega \| 12\ \Omega$

    $= 1\ \Omega \| 12\ \Omega$

    $= 0.9231\ \Omega$

    $\underset{+-}{V_{ab}} = -I_TR_T = -(7\text{ A})(0.9231\ \Omega) = \mathbf{-6.462\ V}$

    c. $I\uparrow = \dfrac{6.462\text{ V}}{6\ \Omega} = \mathbf{1.077\ A}$

12. a. $\overrightarrow{I_1}\downarrow I_3 \overleftarrow{\ } I_2$

    $4 - 4I_1 - 8I_3 = 0$

    $6 - 2I_2 - 8I_3 = 0$

    $I_1 + I_2 = I_3$

    $I_1 = -\dfrac{1}{7}\text{ A},\ I_2 = \dfrac{5}{7}\text{ A},\ I_3 = \dfrac{4}{7}\text{ A}$

    $I_{R_1} = I_1 = -\dfrac{1}{7}\text{ A},\ I_{R_2} = I_2 = \dfrac{5}{7}\text{ A},\ I_{R_3} = I_3 = \dfrac{4}{7}\text{ A}$

b. $I_1 \uparrow I_3 \; I_2$

$$10 + 12 - 3I_3 - 4I_1 = 0$$
$$12 - 3I_3 - 12I_2 = 0$$
$$I_1 + I_2 = I_3$$

$I_1$ = **3.0625 A**
$I_2$ = **0.1875 A**
$I_3$ = **3.25 A**

$I_{R_1} = I_1 =$ **3.0625 A**, $I_{R_2} = I_2 =$ **3.25 A**
$I_{R_3} = I_3 =$ **0.1875 A**

14. (I): $I_1 \downarrow I_3 \downarrow I_2$

$$-25 - 2I_1 - 3I_3 + 60 = 0$$
$$-60 + 3I_3 + 6 - 5I_2 - 20 = 0$$
$$I_1 = I_2 + I_3$$

$I_2 =$ **−8.548 A**

$V_{ab} = 20\text{ V} - I_2 5\ \Omega$
$= 20\text{ V} - (8.548\text{ A})(5\ \Omega)$
$=$ **−22.75 V**

(II): Source conversion: $E = IR_1 = (3\text{ A})(3\ \Omega) = 9\text{ V}$, $R_1 = 3\ \Omega$

$I_2 \downarrow I_4 \downarrow I_3$

$$9 + 6 - 3I_2 - 4I_2 - 6I_4 = 0$$
$$+ 6I_4 - 8I_3 - 4 = 0$$
$$I_2 = I_3 + I_4$$

$I_2 =$ **1.274 A**

$V_{ab} = I_2 4\ \Omega - 6\text{V}$
$= (1.274\text{ A})4\ \Omega - 6\text{ V}$
$=$ **−0.904 V**

16. a.

$$20\text{ V} - I_B(270\text{ k}\Omega) - 0.7\text{ V} - I_E(0.51\text{ k}\Omega) = 0$$
$$I_E(0.51\text{ k}\Omega) + 8\text{ V} + I_C(2.2\text{ k}\Omega) - 20\text{ V} = 0$$
$$I_E = I_B + I_C$$

$I_B =$ **63.02 μA**, $I_C =$ **4.416 mA**, $I_E =$ **4.479 mA**

b. $V_B =$ **2.985 V**, $V_E =$ **2.285 V**, $V_C =$ **10.285 V**

c. $\beta \cong$ **70.07**

18. (I): $I_1 \curvearrowright$ $I_2 \curvearrowright$

$$10 - I_1(5.6\text{ k}\Omega) - 2.2\text{ k}\Omega(I_1 - I_2) + 20 = 0$$
$$-20 - 2.2\text{ k}\Omega(I_2 - I_1) - I_2\, 3.3\text{ k}\Omega - 30 = 0$$

$I_1 =$ **1.445 mA**, $I_2 =$ **8.513 mA**

$I_{R_1} = I_1 =$ **1.445 mA**, $I_{R_2} = I_2 =$ **8.513 mA**

$I_{R_3} = I_2 - I_1 =$ **7.068 mA** (direction of $I_2$)

(II): $I_1 \curvearrowright$ $I_2 \curvearrowright$

$$-I_1(1.2\text{ k}\Omega) + 9 - 8.2\text{ k}\Omega(I_1 - I_2) = 0$$
$$-I_2(1.1\text{ k}\Omega) + 6 - I_2\,(9.1\text{ k}\Omega) - 8.2\text{ k}\Omega(I_2 - I_1) = 0$$

$I_1 =$ **2.0337 mA**, $I_2 =$ **1.2316 mA**

$I_{R_1} = I_1 =$ **2.0337 mA**, $I_{R_3} = I_{R_4} = I_2 =$ **1.2316 mA**

$I_{R_2} = I_2 - I_1 = 2.0337\text{ mA} - 1.2316\text{ mA} =$ **0.8021 mA** (direction of $I_1$)

20. $I_1 \curvearrowright$ $I_2 \curvearrowright$ $I_3 \curvearrowright$

$$10 - I_1 2 - 1(I_1 - I_2) = 0$$
$$-1(I_2 - I_1) - I_2\, 4 - 5(I_2 - I_3) = 0$$
$$-5(I_3 - I_2) - I_3\, 3 - 6 = 0$$

$$3I_1 - 1I_2 + 0 = 10$$
$$-1I_1 + 10I_2 - 5I_3 = 0$$
$$0 - 5I_2 + 8I_3 = -6$$

$I_2 = I_{R_3} =$ **−63.694 mA**

22. (I): $I_1 \curvearrowright$ $I_2 \curvearrowright$ $I_3 \curvearrowright$

$$I_1(2.2\text{ k}\Omega + 9.1\text{ k}\Omega) - 9.1\text{ k}\Omega\, I_2 = 18$$
$$I_2(9.1\text{ k}\Omega + 7.5\text{ k}\Omega + 6.8\text{ k}\Omega) - 9.1\text{ k}\Omega\, I_1 - 6.8\text{ k}\Omega\, I_3 = -18$$
$$I_3(6.8\text{ k}\Omega + 3.3\text{ k}\Omega) - I_2\, 6.8\text{ k}\Omega = -3$$

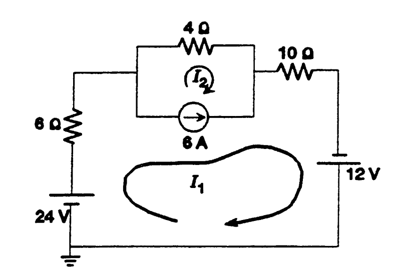
$I_1 =$ **1.2059 mA**, $I_2 =$ **−0.4806 mA**, $I_3 =$ **−0.6206 mA**

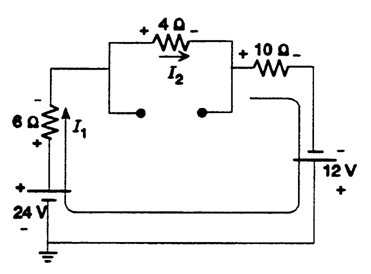
(II): $I_1 \curvearrowright$ $I_3 \curvearrowright$ $I_2 \curvearrowright$

$$16 - 4I_1 - 3(I_1 - I_2) - 12 - 4(I_1 - I_3) = 0$$
$$12 - 3(I_2 - I_1) - 10\, I_2 - 15 - 4(I_2 - I_3) = 0$$
$$-16 - 4(I_3 - I_1) - 4(I_3 - I_2) - 7I_3 = 0$$

$I_1 =$ **−0.2385 A**, $I_2 =$ **−0.5169 A**, $I_3 =$ **−1.278 A**

24. a.




$$24\text{ V} - 6I_1 - 4I_2 - 10I_1 + 12\text{ V} = 0$$

and $16I_1 + 4I_2 = 36$

$I_1 - I_2 = 6\text{ A}$

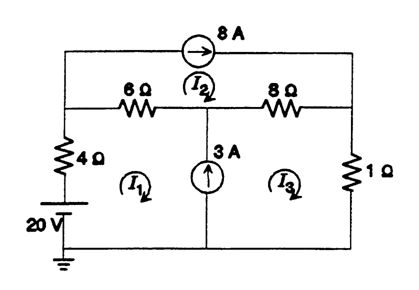
---

$$I_1 = I_2 + 6\text{ A}$$
$$16[I_2 + 6\text{ A}] + 4I_2 = 36$$
$$16I_2 + 96 + 4I_2 = 36$$
$$20I_2 = -60$$
$$I_2 = -3\text{ A}$$
$$I_1 = I_2 + 6\text{ A} = -3\text{ A} + 6\text{ A} = 3\text{ A}$$

$I_{24V} = I_{6\Omega} = I_{10\Omega} = I_{12V} = 3\text{ A (CW)}$

$I_{4\Omega} = 3\text{ A (CCW)}$

b.




$$20\text{ V} - 4I_1 - 6(I_1 - I_2) - 8(I_3 - I_2) - 1I_3 = 0$$
$$10I_1 - 14I_2 + 9I_3 = 20$$
$$I_3 - I_1 = 3\text{ A}$$
$$I_2 = 8\text{ A}$$

---

$$10I_1 - 14(8\text{ A}) + 9[I_1 + 3\text{ A}] = 20$$
$$19I_1 = 105$$
$$I_1 = 5.526\text{ A}$$
$$I_3 = I_1 + 3\text{ A} = 5.526\text{ A} + 3\text{ A} = 8.526\text{ A}$$
$$I_2 = 8$$

$I_{20V} = I_{4\Omega} =$ **5.526 A** (dir. of $I_1$)

$I_{6\Omega} = I_2 - I_1 =$ **2.474 A** (dir. of $I_2$)

$I_{8\Omega} = I_3 - I_2 =$ **0.526 A** (dir. of $I_3$)

$I_{1\Omega} =$ **8.526 A** (dir. of $I_3$)

26. (I): $I_1 \circlearrowright\ I_2 \circlearrowright$

a. $I_1(5.6\text{ k}\Omega + 2.2\text{ k}\Omega) - 2.2\text{ k}\Omega\ (I_2) = 10 + 20$

$I_2(2.2\text{ k}\Omega + 3.3\text{ k}\Omega) - 2.2\text{ k}\Omega\ (I_1) = -20 - 30$

---

b. $I_1 =$ **1.445 mA**, $I_2 =$ **−8.513 mA**

c. $I_{R_1} = I_1 = \mathbf{1.445\ mA}$, $I_{R_2} = I_2 = \mathbf{-8.513\ mA}$

$I_{R_3} = I_1 + I_2 = 8.513\text{ mA} + 1.445\text{ mA} = \mathbf{9.958\ mA}$ (direction of $I_1$)

(II): $I_1 \circlearrowright$

$I_2 \circlearrowright$

a. $I_1(1.2\text{ k}\Omega + 8.2\text{ k}\Omega) - 8.2\text{ k}\Omega\, I_2 = 9$

$I_2(8.2\text{ k}\Omega + 1.1\text{ k}\Omega + 9.1\text{ k}\Omega) - 8.2\text{ k}\Omega\, I_1 = 6$

---

b. $I_1 = \mathbf{2.0316\ mA}$, $I_2 = \mathbf{1.2316\ mA}$

c. $I_{R_1} = I_1 = \mathbf{2.0316\ mA}$, $I_{R_3} = I_{R_4} = I_2 = \mathbf{1.2316\ mA}$

$I_{R_2} = I_1 - I_2 = 2.0316\text{ mA} - 1.2316\text{ mA} = \mathbf{0.8\ mA}$ (direction of $I_1$)

28. $I_1 \circlearrowright\ I_2 \circlearrowright\ I_3 \circlearrowright$

$I_1(2 + 1) - 1I_2 = 10$

$I_2(1 + 4 + 5) - 1I_1 - 5I_3 = 0$

$I_3(5 + 3) - 5I_2 = -6$

---

$I_2 = I_{R_3} = -63.694\text{ mA}$ (exact match with problem 15)

30. (I): $I_1 \circlearrowright\ I_2 \circlearrowright\ I_3 \circlearrowright$

$(2.2\text{ k}\Omega + 9.1\text{ k}\Omega)I_1 - 9.1\text{ k}\Omega\, I_2 = 18$

$(9.1\text{ k}\Omega + 7.5\text{ k}\Omega + 6.8\text{ k}\Omega)I_2 - 9.1\text{ k}\Omega\, I_1 - 6.8\text{ k}\Omega\, I_3 = -18$

$(6.8\text{ k}\Omega + 3.3\text{ k}\Omega)I_3 - 6.8\text{ k}\Omega\, I_2 = -3$

---

$I_1 = \mathbf{1.2059\ mA}$, $I_2 = \mathbf{-0.4806\ mA}$, $I_3 = \mathbf{-0.6206\ mA}$

(II): $I_1 \circlearrowright$

$I_3 \circlearrowright\ I_2 \circlearrowright$

$(4\ \Omega + 4\ \Omega + 3\ \Omega)I_1 - 3\ \Omega\, I_2 - 4\ \Omega\, I_3 = 16 - 12$

$(4\ \Omega + 3\ \Omega + 10\ \Omega)I_2 - 3I_1 - 4\ \Omega\, I_3 = 12 - 15$

$(4\ \Omega + 4\ \Omega + 7\ \Omega)I_3 - 4I_1 - 4I_2 = -16$

---

$I_1 = \mathbf{-0.2385\ A}$, $I_2 = \mathbf{-0.5169\ A}$, $I_3 = \mathbf{-1.278\ A}$

32. a. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2} + \frac{1}{5} + \frac{1}{2}\right] - \frac{1}{2}V_2 = 5 \qquad V_1 = \mathbf{8.077\ V}$$

$$V_2 = \mathbf{9.385\ V}$$

$$V_2\left[\frac{1}{2} + \frac{1}{4}\right] - \frac{1}{2}V_1 = 3$$

---

Symmetry is present

b. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2}+\frac{1}{4}\right]-\frac{1}{4}V_2 = 4-2 \qquad V_1 = \mathbf{4.8\ V}$$

$$V_2\left[\frac{1}{4}+\frac{1}{20}+\frac{1}{5}\right]-\frac{1}{4}V_1 = 2 \qquad V_2 = \mathbf{6.4\ V}$$

Symmetry is present

34. (I): a. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2.2\text{ k}\Omega}+\frac{1}{9.1\text{ k}\Omega}+\frac{1}{7.5\text{ k}\Omega}\right]-\frac{1}{7.5\text{ k}\Omega}V_2 = -1.978\text{ mA}$$

$$V_2\left[\frac{1}{7.5\text{ k}\Omega}+\frac{1}{6.8\text{ k}\Omega}+\frac{1}{3.3\text{ k}\Omega}\right]-\frac{1}{7.5\text{ k}\Omega}V_1 = 0.909\text{ mA}$$

b. $V_1 = \mathbf{-2.653\ V}$, $V_2 = \mathbf{0.952\ V}$

c. $V_{R_3} = V_1 = \mathbf{-2.653\ V}$, $V_{R_5} = V_2 = \mathbf{0.952\ V}$, $V_{R_4} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{3.605\ V}$

$R_1$ $\overset{+}{\underset{-}{V_{R_1}}} = 18\text{ V} - 2.653\text{ V} = \mathbf{15.347\ V}$

$R_2$ (− top, + bottom) $V_{R_2} = 3\text{ V} - 0.952\text{ V} = \mathbf{2.048\ V}$

(II): a. $\circ V_1 \quad \circ V_2 \quad \circ V_3$ (ground)

$$V_1\left[\frac{1}{4}+\frac{1}{4}+\frac{1}{7}\right]-\frac{1}{4}V_2-\frac{1}{4}V_3 = 4$$

$$V_2\left[\frac{1}{4}+\frac{1}{3}+\frac{1}{10}\right]-\frac{1}{4}V_1-\frac{1}{3}V_3 = 4+1.5$$

$$V_3\left[\frac{1}{4}+\frac{1}{3}+\frac{1}{4}\right]-\frac{1}{4}V_1-\frac{1}{3}V_3 = -4-4$$

b. $V_1 = \mathbf{8.877\ V}$, $V_2 = \mathbf{9.831\ V}$, $V_3 = \mathbf{-3.005\ V}$

c. $V_{R_6} = V_1 = \mathbf{8.877\ V}$, $V_{R_4} = V_3 = \mathbf{-3.005\ V}$, $V_{R_5} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = \mathbf{0.954\ V}$

$R_1$ ($-V_{R_1}+$) $V_{R_1} = 16\text{ V} - V_1 + V_3 = \mathbf{4.118\ V}$

$R_2$ ($-V_{R_2}+$) $V_{R_2} = V_2 - V_3 - 12\text{ V} = \mathbf{0.836\ V}$

$R_3$ (− top, + bottom) $V_{R_3} = 15\text{ V} - V_2 = \mathbf{5.169\ V}$

36. (I) $\circ V_1 \quad \circ V_2 \quad \circ V_3$

$$\left[\frac{1}{2} + \frac{1}{2}\right] V_1 - \frac{1}{2}V_2 + 0 = -5$$

$$\left[\frac{1}{2} + \frac{1}{9} + \frac{1}{7} + \frac{1}{2}\right] V_2 - \frac{1}{2}V_1 - \frac{1}{2}V_3 = 0$$

$$\left[\frac{1}{2} + \frac{1}{2} + \frac{1}{4}\right] V_3 - \frac{1}{2}V_2 = 5$$

**$V_1$ = −5.311 V, $V_2$ = −0.6219 V, $V_3$ = 3.751 V**

(II) $\circ V_1 \quad \circ V_2 \quad \circ V_3$

$$V_1\left[\frac{1}{2} + \frac{1}{6}\right] - \frac{1}{6}V_3 = -5$$

$$V_2\left[\frac{1}{4}\right] = 5 - 2$$

$$V_3\left[\frac{1}{6} + \frac{1}{5}\right] - \frac{1}{6}V_1 = 2$$

**$V_1$ = −6.917 V, $V_2$ = 12 V, $V_3$ = 2.3 V**

38. a. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2} + \frac{1}{5} + \frac{1}{2}\right] - \frac{1}{2}V_2 = 5$$

$$V_2\left[\frac{1}{2} + \frac{1}{4}\right] - \frac{1}{2}V_1 = 3$$

**$V_1$ = 8.077 V, $V_2$ = 9.385 V**

Symmetry present

b. $\circ V_1 \quad \circ V_2$

$$V_1\left[\frac{1}{2} + \frac{1}{4}\right] - \frac{1}{4}V_2 = 4 - 2$$

$$V_2\left[\frac{1}{4} + \frac{1}{20} + \frac{1}{5}\right] - \frac{1}{4}V_1 = 2$$

**$V_1$ = 4.8 V, $V_2$ = 6.4 V**

Symmetry present

40. (I): a. Source conversion: $I = 5$ A, $R = 3\ \Omega$

$\circ V_1 \quad \circ V_2 \quad \circ V_3$

$$V_1\left[\frac{1}{3} + \frac{1}{6} + \frac{1}{6}\right] - \frac{1}{6}V_2 - \frac{1}{6}V_3 = 5$$

$$V_2\left[\frac{1}{6} + \frac{1}{4} + \frac{1}{5}\right] - \frac{1}{6}V_1 - \frac{1}{5}V_3 = -3$$

$$V_3\left[\frac{1}{6} + \frac{1}{5} + \frac{1}{7}\right] - \frac{1}{5}V_2 - \frac{1}{6}V_1 = 0$$

b. $V_1 = \mathbf{7.238\ V}$, $V_2 = \mathbf{-2.453\ V}$, $V_3 = \mathbf{1.405\ V}$

c. $R_1$ (resistor, $-$ on top, $+$ below) $V_{R_1} = 15\text{ V} - 7.238\text{ V} = \mathbf{7.762\ V}$

$V_{R_2} = V_2 = \mathbf{-2.453\ V}$, $V_{R_3} = V_3 = \mathbf{1.405\ V}$

$V_{R_4} = \overset{(+)}{V_3} - \overset{(-)}{V_2} = 1.405\text{ V} - (-2.453\text{ V}) = \mathbf{3.858\ V}$

$V_{R_5} = V_1 - V_2 = 7.238\text{ V} - (-2.453\text{ V}) = \mathbf{9.691\ V}$

$V_{R_6} = V_1 - V_3 = 7.238\text{ V} - 1.405\text{ V} = \mathbf{5.833\ V}$

(II): a. Source conversion: $I = 4\text{ A}$, $R = 4\ \Omega$

$\circ V_1 \quad \circ V_2 \quad \circ V_3$

$$V_1\left[\frac{1}{9} + \frac{1}{20} + \frac{1}{20}\right] - \frac{1}{20}V_2 - \frac{1}{20}V_3 = -2$$

$$V_2\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{18}\right] - \frac{1}{20}V_1 - \frac{1}{20}V_3 = 0$$

$$V_3\left[\frac{1}{20} + \frac{1}{20} + \frac{1}{4}\right] - \frac{1}{20}V_2 - \frac{1}{20}V_1 = 4$$

b. $V_1 = \mathbf{-6.642\ V}$, $V_2 = \mathbf{1.293\ V}$, $V_3 = \mathbf{10.664\ V}$

c. $V_{R_1} = V_1 = \mathbf{-6.737\ V}$, $R_2$ (resistor, $-$ on top, $+$ below) $V_{R_2} = 16\text{ V} - 10.676\text{ V} = \mathbf{5.324\ V}$

$V_{R_3} = V_2 = \mathbf{1.288\ V}$, $V_{R_4} = \overset{(+)}{V_2} - \overset{(-)}{V_1} = 1.288\text{ V} - (-6.737\text{ V}) = \mathbf{8.025\ V}$

$V_{R_5} = \overset{(+)}{V_3} - \overset{(-)}{V_2} = 10.676\text{ V} - 1.288\text{ V} = \mathbf{9.388\ V}$

$V_{R_6} = \overset{(+)}{V_3} - \overset{(-)}{V_1} = 10.676\text{ V} - (-6.737\text{ V}) = \mathbf{17.413\ V}$

42. a. ($I_1$, $I_2$, $I_3$ clockwise loops)

$I_1(6 + 5 + 10) - 5I_2 - 10I_3 = 6$
$I_2(5 + 5 + 5) - 5I_1 - 5I_3 = 0$
$I_3(5 + 10 + 20) - 10I_1 - 5I_2 = 0$

$I_1 = \mathbf{0.3934\ A}$, $I_2 = \mathbf{0.1770\ A}$, $I_3 = \mathbf{0.1377\ A}$

b. $I_5 = I_2 - I_3 = 39.34$ mA (direction of $I_2$)

c, d. no

44. a. ($I_1$, $I_2$, $I_3$ clockwise loops)

$I_1(2\text{ k}\Omega + 33\text{ k}\Omega + 3.3\text{ k}\Omega) - 33\text{ k}\Omega\, I_2 - 3.3\text{ k}\Omega\, I_3 = 24$
$I_2(33\text{ k}\Omega + 56\text{ k}\Omega + 36\text{ k}\Omega) - 33\text{ k}\Omega\, I_1 - 36\text{ k}\Omega\, I_3 = 0$
$I_3(3.3\text{ k}\Omega + 36\text{ k}\Omega + 5.6\text{ k}\Omega) - 36\text{ k}\Omega\, I_2 - 3.3\text{ k}\Omega\, I_1 = 0$

$I_1 = \mathbf{0.9662\ mA}$, $I_2 = I_3 = \mathbf{0.3583\ mA}$

b. $I_5 = I_2 - I_3 = 0.3583 \text{ mA} - 0.3583 \text{ mA} = \mathbf{0}$

c, d. yes

46. Source conversion: $I = 9 \text{ mA}, R = 1 \text{ k}\Omega$

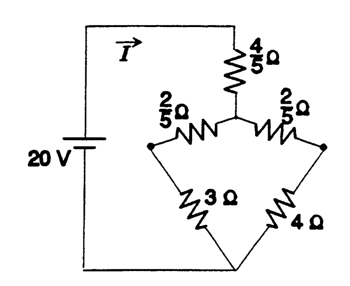
$V_1$ $V_2$ $V_3$

$$V_1\left[\frac{1}{1 \text{ k}\Omega} + \frac{1}{100 \text{ k}\Omega} + \frac{1}{200 \text{ k}\Omega}\right] - \frac{1}{100 \text{ k}\Omega}V_2 - \frac{1}{200 \text{ k}\Omega}V_3 = 4 \text{ mA}$$

$$V_2\left[\frac{1}{100 \text{ k}\Omega} + \frac{1}{200 \text{ k}\Omega} + \frac{1}{1 \text{ k}\Omega}\right] - \frac{1}{100 \text{ k}\Omega}V_1 - \frac{1}{1 \text{ k}\Omega}V_3 = -9 \text{ mA}$$

$$V_3\left[\frac{1}{200 \text{ k}\Omega} + \frac{1}{100 \text{ k}\Omega} + \frac{1}{1 \text{ k}\Omega}\right] - \frac{1}{200 \text{ k}\Omega}V_1 - \frac{1}{1 \text{ k}\Omega}V_2 = 9 \text{ mA}$$

48. a.

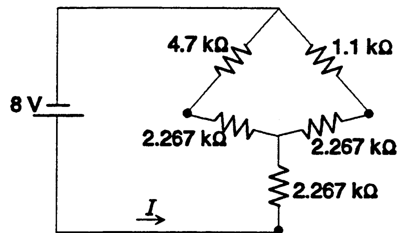



$$I = \frac{20 \text{ V}}{\frac{4}{5}\ \Omega + \left[\frac{2}{5}\ \Omega + 3\ \Omega\right] \| \left[\frac{2}{5}\ \Omega + 4\ \Omega\right]}$$

$$= \frac{20 \text{ V}}{\frac{4}{5}\ \Omega + (3.14\ \Omega) \| (4.4\ \Omega)}$$

$$= \mathbf{7.358\ A}$$

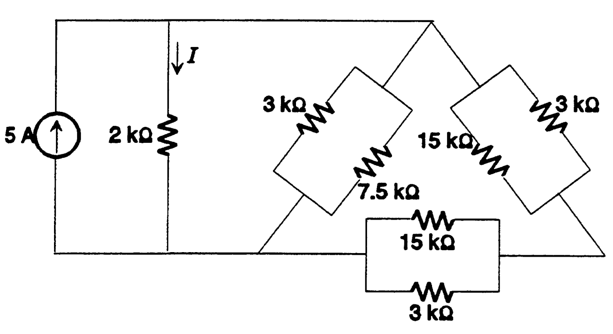
b.




$$R_T = 2.267 \text{ k}\Omega + [4.7 \text{ k}\Omega + 2.267 \text{ k}\Omega] \| [1.1 \text{ k}\Omega + 2.267 \text{ k}\Omega]$$
$$= 2.267 \text{ k}\Omega + [6.967 \text{ k}\Omega] \| [3.367 \text{ k}\Omega]$$
$$= 2.267 \text{ k}\Omega + 2.27 \text{ k}\Omega$$
$$= 4.537 \text{ k}\Omega$$

$$I = \frac{8 \text{ V}}{4.537 \text{ k}\Omega} = \mathbf{1.763\ mA}$$

50.

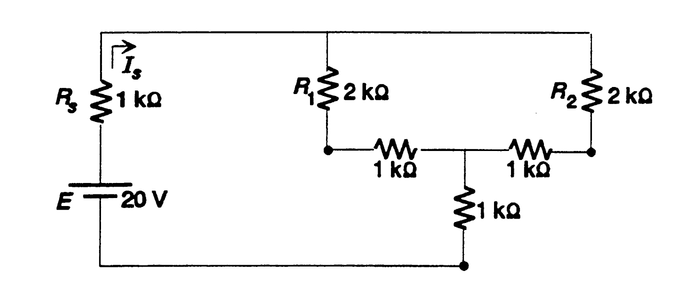



$3 \text{ k}\Omega \| 7.5 \text{ k}\Omega = 2.14 \text{ k}\Omega$
$3 \text{ k}\Omega \| 15 \text{ k}\Omega = 2.5 \text{ k}\Omega$

$$R'_T = 2.14 \text{ k}\Omega \| (2.5 \text{ k}\Omega + 2.5 \text{ k}\Omega) = 1.499 \text{ k}\Omega$$

CDR: $$I = \frac{(1.499 \text{ k}\Omega)(5 \text{ A})}{1.499 \text{ k}\Omega + 2 \text{ k}\Omega} = \mathbf{2.143\ A}$$

52.




$$R' = R_1 + 1\text{ k}\Omega = 3\text{ k}\Omega$$
$$R'' = R_2 + 1\text{ k}\Omega = 3\text{ k}\Omega$$
$$R'_T = \frac{3\text{ k}\Omega}{2} = 1.5\text{ k}\Omega$$

$$R_T = 1\text{ k}\Omega + 1.5\text{ k}\Omega + 1\text{ k}\Omega = 3.5\text{ k}\Omega$$
$$I_s = \frac{E}{R_T} = \frac{20\text{ V}}{3.5\text{ k}\Omega} = \mathbf{5.714\text{ mA}}$$